WEST AFRICAN COCOA RESEARCH INSTITUTE

QUARTERLY PROGRESS REPORT

No. 49

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WEST AFRICAN COCOA RESEARCH INSTITUTE

TAFO, GHANA

FORTY-NINTH QUARTERLY REPORT

JANUARY-MARCH, 1958

Any results recorded in this Progress Report should not be accepted as conclusive. The report contains interim information only. Final results are published in WACRI Technical Bulletins and elsewhere.

SENIOR STAFF

Director	J. Lamb (on leave 23rd March)
Deputy Director	C.G. Johnson (on leave)
Scientific Assistant to Director	G.A. Jones
Secretary	H.L. Pugh (returned from leave 7th March)
Assistant Accountant	J.N.A. Hyde
Office Assistant/Librarian	Audrey Bryan (on leave 27th March prior to resignation)
	June Nicholas (temporary)

TAFO STATION

Division of Entomology	P.F. Entwistle
Division of Pathology	J.W. Blencowe
	A.L. Wharton (on leave 16th February)
	A.A.F. Brunt
	A. Attafuah
Division of Botany	D.R. Glendinning (on leave 26th March)
	R.G. Hurd
Division of Chemistry	T.A. Rohan (on leavo 1st January prior to resignation)
	R.H. Kenten
	E. Margaret Holden (on leave 12th February, pending termination of secondment)
	R.K. Cunningham
Division of Agronomy	R.J. Benstead (on leave 12th March prior to retirement)
	R.W. Smith
	J.F. Longworth
Statistician	C. de Jonge (arrived 20th March)
Laboratory Technicians (electronics)	A.J.H. Arnold
(spectrography)	J.C. Burridge
Plantation Manager	H.W.S. Allison (returned from leave 19th March)
Maintenance Engineer	A. Maddison
Works Superintendent	E.K. Berko
Guide-Demonstrator	F.E. Decker
Station Manager	S.E. Ntim-Kwafo

IBADAN SUB-STATION

Deputy Director (Nigeria)	T.W. Tinsley
Entomologists	R.G. Donald
	C.K.H. Martini
Pathologists	J.M. Thresh
	D. Kay
	E.C. Hislop

MANAGING COMMITTEE

The twenty-third meeting of the Managing Committee was held at Tafo on the 11th and 12th February. The Technical Sub-Committee met at Ibadan on the 3rd and 4th January.

STAFF MATTERS

The Director flew to the United Kingdom on leave on the 23rd March. Dr. Blencowe will be Acting Director until Dr. Johnson returns from leave in April. Mr. C. de Jonge, Statistician, joined the staff of the Institute in March.

Mr. R.J. Benstead, who has been with the Instituto since its foundation, went on retirement leave in March. Mr. Benstead has spent more than 30 years in West Africa, and his wide experience will be greatly missed. Dr. T.A. Rohan and Miss A. Bryan have resigned. Miss E. Margaret Holden has returned to her substantive post at Rothamsted Experimental Station.

A team of specialists are being seconded from the Colonial Pesticides Research Unit, Arusha, Tanganyika, to form a West African Fungicides Research Unit which will be attached to the Institute's Sub-Station at Ibadan and will work initially on the fungicidal control of black-pod disease. Mr. E.C. Hislop, the mycologist of the Unit, arrived at Ibadan in February.

Several members of the staff from Tafo and Ibadan attended the Conference at Achimota organised by the West African Science Association.

VISITORS

The Institute was honoured by a visit from His Excellency the Governor-General of Ghana, accompanied by the Commissioner for the Eastern Region, in January. The Minister of Agriculture, and Mr. E.W.T. Gill, the Canadian High Commissioner in Ghana also visited the Station. Other visitors have included Professor Lewis, Economic Adviser to the Prime Minister; Dr. Stoughton, Principal of the University College of Ghana; Mr. R.H. Pinder of the I.C.A. Mission in Ghana; Mr. A.H. Reed of the U.K. Commonwealth Relations Office; Professor J.V. Phillips of the University College of Ghana; Mr. Nathan-Marsh, Secretary of the Nigerian Produce Marketing Co. Ltd.; and Mr. Lains e Silva of the Coffee Board of Portugal.

His Excellency the Governor-General of the Federation of Nigeria and Lady Robertson paid an unofficial visit to the Ibadan Sub-Station in March. Other visitors to the Sub-Station have included Professor E.T.C. Spooner of the London School of Hygiene and Tropical Medicine; Mr. A.G. Simpson, Acting Permanent

Secretary of the Ministry of Agriculture and Natural Resources, Sierra Leone; and Professor Patrick Collard of the University College of Ibadan.

MANAGEMENT AND MAINTENANCE

The construction of the six new bungalows in the residential area at Tafo has been completed, and four of them have been occupied. A changeover from D.C. to A.C. electricity supply was effected in January, without serious mishap. An extensive programme of road improvements has been started.

At the Ibadan Sub-Station the construction of two additional Senior Staff houses has been started.

CROP DELIVERY

The number of pods harvested during the quarter is shown below:

Month	Old Station	Square Mile	Total
January	42,117	10,762	52,879
February	5,453	1,451	6,904
March	706	235	941
Total	48,276	12,448	60,724

Production of dry cocoa amounted to 111,314 lb. during 1957-58, compared with 91,408 lb. in the previous year, and annual revenue showed a corresponding increase from approximately £5,600 to £6,750. This improvement can be attributed in part to the maintenance of regular harvesting, every seven to ten days, throughout the season.

SWOLLEN SHOOT DISEASE

Monthly losses from the Uniformity Trial Areas, Old Station, due to swollen shoot disease and other causes are given below:

Month	Trees destroyed		Total	Infected seedlings removed
	Swollen Shoot	Undiagnosed		
January	45	4	49	57
February	46	5	51	66
March	44	1	45	66
Total	135	10	145	189

The numbers of infected and contact trees removed from the Institute's land have continued to decrease this quarter, and they are now comparable to the average numbers removed before the re-organisation of the control methods in August, 1957 (Quarterly Report No. 47). It remains to be seen if this improvement will continue in the 1958-59 season.

A total of 907 infected trees were removed from the Square Mile and the Old Station.

UPPER AMAZON SEED

A total of 16,549 F3 pods were dispatched to Nigeria and the Cameroons during the quarter, made up as follows:

Western Region	14,943
Eastern Region	500
Northern Region	276
Cameroons	830

METEOROLOGY

Month	1957		20-year mean	
	Rainfall (in.)	Wet days	Rainfall (in.)	Wet days
January	1.97	7	1.52	3.6
February	3.00	8	3.62	7.0
March	6.64	15	5.85	11.7
Total	11.61	30	10.99	22.3

T A F O S T A T I O N

PATHOLOGY DIVISION

VIRUS RESEARCH

Further results of the enquiry into the prevalence of undetected swollen shoot virus in an area of Amelonado cacao (Quarterly Report No. 48) are now available. Of 63 trees known to be infected, two-thirds have so far shown symptoms after coppicing, and of 158 trees in physical contact with these infected trees, one-fifth have now shown symptoms. Fifty-six of the 498 presumed healthy trees that were coppiced have been found to be infected. A further 300 trees of little economic value, but presumed healthy, have been coppiced.

A factorial experiment has been started to compare the effect of infection by mild 1A virus, by severe 1A, and by both viruses introduced simultaneously, on the growth attributes of Amelonado and Amazon seedlings. Samples are taken at fourteen-day intervals, and stem height, leaf number, leaf area, and wet and dry weights recorded.

Comparisons are being made of the efficiency of several species of mealybugs as vectors of a number of virus isolates.

STUDIES ON BLACK-POD DISEASE

Three new field experiments on the chemical control of black-pod have been started on yield-recordod Amelonado cacao.

The first, to be carried out in conjunction with the Chemistry Division (see p. 18), is designed to compare the effects of regular spraying with a commercial copper oxide formulation and with carbide-bordeaux. Other treatments include the application of copper sulphate to the soil and to the foliage, in an effort to detect any possible fertility effects of the copper.

The second experiment compares the effects of spraying cacao pods with carbide-bordeaux at different times of the year, in an attempt to improve the present spray programme which involves ten applications at three-weekly intervals. The third experiment is designed to yield information on the response to a fungicidal spray when a general fertilizer dressing has been applied. A proprietary copper-oxide preparation is being used.

ENTOMOLOGY DIVISION

CAPSID STUDIES

Joint WACRI and Department of Agriculture capsid control trials

In the small-scale units of the current series of capsid trials (see Quarterly Report No. 46) the gamma-BHC plots have shown a greater degree of control than have the aldrin plots, where there was considerable damage in the adjacent untreated plots. Damage in the untreated plots as a whole has been heavy.

In the large-scale units dieldrin has given a relatively low degree of control, and this treatment has been abandoned, the unit being re-allocated to gamma-BHC. Damage in the endrin unit has remained virtually nil and very little damage has been reported from BHC treated areas. Scattered damage has been found throughout the aldrin unit, which is particularly heavily affected along the perimeter.

MEALYBUG STUDIES

Joint WACRI and Department of Agriculture trials on mealybug control

1. Oyoko. During the quarter, ant populations have become firmly re-established, and the numbers of active nests have increased to pre-treatment levels. Populations of adult mealybugs in the treated area also rose from about 5.0 per cent to 12.5 per cent of pre-treatment levels, corresponding to an increase of from 5.7 per cent to 26.1 per cent of control plot levels.

Counts to hand-height continue to be a good indication of the fluctuations in the total numbers of adult mealybugs; this is shown by the close correlation between hand-height counts and counts made on complete felled contact trees in the treated area.

Thus the two applications of dieldrin made in the treated area have been sufficient, through ant control, to effect a minimum reduction of 90 per cent in mealybug populations for a period of twelve months. To date this diminution in vector populations has had no apparent reflection in data collected on the incidence of swollen-shoot disease in the area. Since the maximum latency period of these viruses is of the order of two years, counts of diseased trees must continue for at least one more year before any conclusions may be made as to the success of this new attempt at the control of swollen shoot disease. In order to maintain vector control further spraying is being contemplated.

2. Isolated outbreaks. These trials were ended on the 3rd of January, 1958, having run for a period of twelve months from the

date of the first dieldrin application. At the end of the experiment ant populations were close to pre-treatment levels, a situation that had persisted for some months and is probably to be explained by the small size of the plots treated.

Naturally, with ants re-established early, mealybug control was less effective than in the larger Oyoko trial. By the eighth fortnight after the first dieldrin application populations of adult mealybugs had fallen to 2.5 per cent of pre-treatment levels: but from then on there was a steady increase until, by the close of the experiment at the 25th fortnight after the first treatment, populations had risen to 16.6 per cent of their initial level.

Changes in numbers of trees infested (as measured in counts of mealybugs to hand-height on the trees) followed a similar pattern, falling from an initial level of 26.2 per cent to 5.2 per cent at the ninth fortnight after the first treatment, and rising to 12.3 per cent at the conclusion of the experiment.

Counts of virus incidence, which have also been discontinued, did not demonstrate any control of swollen shoot disease.

3. Square Mile. During the past quarter populations of adult mealybugs in the dieldrin treated area have exceeded those in the controls, whilst the percentage of trees infested is now almost identical in the two treatments. The trial, having reached the limit of its usefulness, will be ended shortly and a more detailed report presented later.

POLLINATION STUDIES

The effects of insecticides on pollination, setting and insect numbers

This experiment, first set up in May 1957, is due to finish at the end of April this year when it will have run for a period of twelve months.

With the sharp rise in flower density during the quarter, to a level similar to that existing at the beginning of the experiment, there has been a corresponding increase in the amount of pollination. However, there is no clear difference between the amount of pollination in the three treatments (dieldrin, gamma-BHC and unsprayed controls).

Setting has followed the pattern described for pollination and flower density.

In Quarterly Report No. 48 it was stated that no differences in insect density had been observed between the three

treatments. The insects referred to were a mixture of Diptera (principally Cecidomyidae and Drosophilidae), Hymenoptera (ants and small Parasitica), Aphidae and Collembola. The pollinating Ceratopogonidae formed a very small proportion of this complex and in the first 48 weeks of the experiment only 191 individuals were found. These were distributed between the three treatments in the following way:-

TABLE I

Percentage distribution of Ceratopogonidae in insects collected from cacao flowers

	Dieldrin Treatment	gamma-BHC Treatment	Unsprayed Control
First 24 weeks	28.6	19.5	58.7
Second 24 weeks	21.2	36.2	42.5
Total 48 weeks	21.4	27.7	50.7

Whilst pollinator populations are lower in the insecticide treated plots than in the controls, there is no reflection of this state in the pollination counts.

During the quarter total insect numbers declined gradually in the first two months from about 10 per hundred flowers to 1-2 per hundred, and in the last month rose to 4-5 per hundred. This is probably a seasonal trend governed by rainfall.

MARMARA STUDIES

The incidence of pod-husk miner (Marmara sp.) in relation to ant and capsid spraying

In previous Quarterly Reports (Nos. 47 and 48) mention was made of increased incidence of pod-husk miner (Marmara sp.), which was associated with the use of insecticides against capsids and ants. The evidence presented in Quarterly Report No. 48 was for Marmara on pods but during the past quarter further data have been collected for incidence on fan tissue.

Corresponding to the association reported between pod infestation on unsprayed plots and the distance from the nearest sprayed plot, a similar association has been found between fan tissue damage and distance from a sprayed area. The figures are not as clear-cut, however, as those for pod infestation. During the past six months no plots have been sprayed with dieldrin, and

all plots, whether or not they were previously treated with dieldrin, have received two applications of gamma-BHC. The cessation of dieldrin spraying would allow parasite populations to return to a more even distribution, whilst the application of BHC to all plots would tend to equalise the effects of this more normal parasite distribution, so inducing a similar intensity of Marmara attack in the two treatments. This is also illustrated in Table II, which shows a similar degree of miner damage in plots which have previously been treated with dieldrin and those which have not. These results may be contrasted with the earlier data presented in the previous Report.

TABLE II

Marmara damage on fan tissue

	Degree of damage (% fan surface damaged by miner)			
	0	1-30	30-60	60-100
Unsprayed plots				
Number of fans	1642	1498	632	717
Percentage of total	36.5	33.3	14.0	15.9
	69.8		29.9	
Sprayed plots				
Number of fans	1535	1781	908	776
Percentage of total	30.7	35.6	18.1	15.5
	66.3		33.6	

The control of Marmara sp.

Experiments have been carried out on the insecticidal control of pod-husk miner. The insecticide selected was the semi-systemic diethyl paranitrophenyl thiophosphate (Bayer, Folidol E-605), which was applied by means of a pressure-retaining knapsack-type sprayer as an aqueous emulsion. Following the manufacturers suggestions that a concentration of 0.06% should be employed against borers (e.g. Codling Moth larvae) a small pilot trial was conducted.

Using three different concentrations of Folidol on three groups of 10 infested pods and 10 infested chupons (average infestation rate approximately three insects per pod or chupon), with equal numbers as untreated controls, estimates of larval

mortality were made two days after spraying. The results are presented in Table III.

TABLE III

Percentage* control of Marmara sp.

Tissue treated	Concentration of Folidol		
	0.06%	0.02%	0.01%
Pods	85.0	97.4	87.8
Chupons	82.6	95.6	100.0

* Calculated by Abbotts' formula: $\frac{c - t}{c} \times 100$,

where c = % alive in control
and t = % alive in treatment.

The figures in the body of the Table represent percentage control as calculated by Abbotts' formula, which takes into account mortality in control treatments. Due to the small samples taken the results naturally show some inconsistencies, but it was apparent that using Folidol at a concentration of 0.01% good control could be obtained.

Hence, in a second series of pilot trials 0.01% was selected as the maximum concentration, whilst two lower concentrations, 0.005% and 0.0025%, were also included. Due to the absence of suitably infected pods this second series was tested entirely on chupon tissue. Percentage control was estimated 1, 2, 3, 4, 5 and 6 days after treatment using one hundred chupons (average infestation rate approximately 125 insects per 100 chupons) for each day/concentration and a similar number for untreated controls. Table IV shows the mortalities obtained.

TABLE IV

Percentage mortality of Marmara sp.

% concentration Folidol E-605	Days after spraying					
	1	2	3	4	5	6
0.01	79.7	98.9	97.5	98.3	98.0	98.8
0.005	73.4	85.8	87.1	81.8	88.7	93.8
0.0025	47.8	62.7	71.9	80.2	77.2	83.0

Slight incongruities in this Table are probably due to variable numbers of larvae in the process of moulting at the time of treatment : during moulting insects do not feed, and it is possible that when the process is complete the insecticide will have decayed to a non-lethal level. This contention has some supporting evidence from the manufacturers, who state that the residual effect within plant tissues is of the order of 2-3 days.

The figures in Table IV, when graphed, give asymptotic curves indicating that the fullest possible degree of control has been obtained by the sixth day. It appears that, provided there is adequate coverage, a concentration of 0.01% gives an acceptable degree of control, though this has yet to be confirmed in larger scale experiments on both pods and chupons.

MINOR PESTS OF CACAO

Scolytidae

Following a report from the Director of Agriculture for Sierra Leone that boring beetles were preventing the establishment of cacao seedlings there, insects and specimens of damaged tissue were obtained. The West African Timber Borer Research Unit in Kumasi tentatively identified the beetles as Xyleborus morstatti Hag., whilst an entomologist in Sierra Leone considered that they might be X.compactus, known there as a pest of coffee. As there appears to be some confusion, specimens have been sent to the Commonwealth Institute of Entomology in London for correct identification.

The damage symptoms reported, and those seen in the infested chupons sent to this Institute, are similar in nature to those previously reported from the Ivory Coast, where infestation is considered to be a dry season phenomenon, though none-the-less of a fairly serious nature.

The above report stimulated interest in this family of beetles at Tafo and in a space of two weeks 10 different species (8 of them ambrosia beetles) were recovered from dead and dying cacao tissues. Of particular interest was the attack by Scolytidae observed in a group of about 15 mature trees dying from unknown causes. Attack began very soon after the first appearance of mortality symptoms; it was concentrated at litter level but extended to over 10 feet up the trunk and to more than 15 inches below soil level. The following species (tentatively identified by W.A.T.B.R.U.) were recovered from the wood of these trees:-

Xyleborus semigranosus Blandf.
X. (premnobi group) xylocranela Sch.
X. cameroonus Hag.
X. mascarensis Eich.
X. sp.
X. sp.

Xyleborus attack was not the cause of death, for not all the trees which died had scolytid damage. Cotterell (Department of Agriculture Year Book, 1927 and 1929) recorded apparently similar examples of this type of scolytid attack from several areas in West Africa. The true cause of death of the trees is as yet unknown, as it was at the time of Cotterell's publications when it was enigmatically defined as 'morte subite'.

At Tafo, Scolytidae are frequently encountered in cacao tissue that has been previously damaged by some primary pest (e.g. capsids or the Cerambycid beetle Tragocephala gorilla). This is usually terminal fan or chupon tissue and Scolytidae of the biological group known as bark beetles (as opposed to ambrosia beetles) are predominant. These are largely Hypothenemus sp. (probably pusillus Egg.) though two species of Xyleborus (one probably X. sharpae Hokp., the other unidentified) have been noted.

Cerambycidae

Tragocephala gorilla Thomp. has frequently been recorded from cacao in West Africa, particularly in areas east of the Belgian Congo (where it would seem to be replaced by other species of the same genus). Previous observations on its biology are incomplete in that the unique behaviour of the larva has been overlooked.

Attack is principally on chupon tissue but also occasionally on fans. Before laying the egg the adult female beetle first ring-barks the stem at a point which may be anything from two to ten inches below the apical bud. The egg itself is then deposited in a slit about half an inch above the point of ring-bark and is wholly embedded in the tissues. Naturally the stem above dies in a very short while. Upon eclosion the young larva burrows upwards into this dead, or dying tissue, often to the base of the apical bud. Holes for the ejection of frass and excess wood are made at irregular intervals. Subsequently the larva turns round and proceeds to eat the living wood below the point of ring-bark.

In seedlings which have not jorquetted this causes death, or severe damage; where there are fan branches the larva normally passes below the jorquette so that all tissue above dies. Damage

may extend to 24 inches below the site of oviposition.

It is of interest to note that larvae removed from the dead wood, above the ring-barked region, will not accept an artificial burrow made in living wood but will either die or escape. On the other hand, larvae which have already transferred their activities to living wood readily accept it again. The reasons behind this curious behaviour are obscure but could be due to different nutritional requirements of the early instar larvae or to an initial negative geotropism. It has frequently been observed that the upward movement of the young larva is interrupted by the presence of Hypothenemus sp. (Coleoptera, Scolytidae) in the dead termal tissue; whether normal development of such larvae occurs is not known.

Lepidoptera

During the past two quarters routine breeding of lepidopterous larvae collected in the field has been undertaken, and recently more than twenty species of moths were sent to the Commonwealth Institute of Entomology for identification.

Eulophonotus myrmeleon Feld., a well known Megalopygid wood borer recorded from the Belgian Congo to the Ivory Coast, was noted for the first time (at Oyoko) attacking the tap-root of a young bearing tree. There were two entrance holes into the root, one at four inches and the other at 12 inches below soil level, the lower burrow containing two larval parasites and the upper one healthy larva of E.myrmeleon. This species has also been noted several times at Tafo attacking the main trunk of mature trees, which, as far as is known, is its normal habit.

BOTANY DIVISION

PLANT BREEDING AND SELECTION

Preliminary yield data for the 1957-58 season are now available for the Progeny and Introductions Trials at Tafo. The Trinidad Introductions, including the approved Amazon types, have shown a considerable overall increase in yield. Type T12 has given approximately 1500 lb. dry cocoa per acre, despite its low wet to dry conversion ratio (see Quarterly Report No. 48), while most of the other approved types have yielded between 1000 and 1300 lb. per acre.

There have been small increases in yield from the 8th Progeny Trial, which was planted in 1952, and the 9th Progeny Trial, planted in 1954. In the former the best variety last year, WAE5, which then gave 850 lb. per acre, is estimated to have given 1000 lb. per acre this season. The highest yield from the 9th Progeny Trial has been given by type WAE 11, with 1000 lb. per acre. Type WEB2, which was the best variety last year, has averaged about 960 lb. per acre this year.

Experiments have been started to investigate the relation between the vigour of young seedlings, and the performance of the same varieties as mature plants. Preliminary results are encouraging.

Natural pollination

The inconclusive results obtained from the 1st Albinor Plot have been mentioned in earlier reports (see Quarterly Reports Nos. 43 and 44). Data from the larger 2nd Albino Plot, established in 1952, are now available for the two seasons 1956-57 and 1957-58, and they show that even in the centre of the plot, separated from normal cacao by five or six rows of trees, a substantial proportion of pollination is from outside the plot.

The plot consists of a square, thirteen trees by thirteen, planted with an Amelonado clone which when selfed gives a proportion of albino seedlings, but when outcrossed to other cacao gives only normal seedlings. The results of this investigation are complicated by the fact that some pods include a much smaller number of albinos than would be expected from normal pollination within the plot. This effect could arise if the flowers were pollinated twice, once from inside and once from outside the plot, or, more probably, it may be due to mixed pollination, as would be obtained through an insect carrying pollen from both inside and outside the plot. So far as the results are concerned these pollinations may be regarded either as from within or from without the albino plot. In Table V, which shows the proportion of pollination from outside the plot for each row of trees, both approaches have been included.

TABLE V

Percentage pollination estimated as from outside the plot

		Row 1 (Outer)	2	3	4	5 + 6 + 7 (Inner)
A	1956 - 57	47	46	35	32	30
	1957 - 58	42	50	50	30	37
B	1956 - 57	56	53	49	57	60
	1957 - 58	53	63	58	36	49

A: "Mixed" pollinations regarded as from inside the plot.
B: " " " " " outside the plot.

In applying these results to the design of seed gardens it should be remembered that the plot is relatively small, and in addition that the cacao is young and is not flowering as freely as is the surrounding cacao. However, it would appear that wide guard rows will be essential if reasonably pure seed is to be obtained.

PHYSIOLOGY OF NUTRITION, GROWTH AND FRUITING

Water culture

The experiment to investigate the effect of shade on the growth of cacao (see Quarterly Report No. 47) has been abandoned, as the seedlings grown in full sunlight were barely surviving. It is possible that the reflection of light and heat from the aluminium lids of the culture pots was harmful to the leaves, and the experiment will be repeated using brown-painted lids. In these circumstances, however, it may be difficult to maintain a uniform root temperature for the two treatments.

A major water culture experiment has been started, based on a method suggested by M. Homes of I.N.E.A.C. for determining the optimal nutrient solution from the results obtained with six basic solutions containing known proportions of the major elements. Ten cacao seedlings have been set up in each standard solution contained in 5-litre concrete pots painted inside with "bituros", which are maintained in an insectary under approximately 50 per cent sunlight. The solutions are aerated for three minutes every half-hour, and seedling growth is measured at intervals.

The roots of cacao growing in culture solutions rapidly become infected with fungi. To minimise infection in this experiment the stock solutions are kept as sterile as possible, and the roots are dipped into 1 per cent chloramine T for five minutes whenever the nutrient solution is changed (normally every three weeks at present). There have been a few failures, but the majority of the seedlings are growing well.

Shade and Manurial Trial

Records of flowering, flushing, wilted pods, and pods harvested are being taken on sample areas of the Shade and Manurial Trial. Any possible effects of the fertilizers on flowering have been overshadowed by the very large number of flowers produced in the unshaded plots, compared with the shaded plots. In January cherelle wilt reached high proportions in the unshaded plots but was non-existent in the shaded plots. This was probably associated with a peak of flowering which occurred about two weeks earlier in the unshaded areas. Since then wilt has been at a uniformly low level in all treatments.

VEGETATIVE PROPAGATION

Transportation of cuttings

The experiment described in Quarterly Report No. 48 has been repeated, with the addition of a second dip in rooting hormone before re-insertion of the cuttings after treatment. This modification did not increase the survival rate with a good rooting selection, but with a poor rooting selection there appeared to be some improvement. The time at which the cuttings are removed does not appear to be critical - this is fortunate as the rate of root formation varies considerably.

The composition of the rooting medium

A series of rooting media, composed of sand and rotting palm fibre in the proportions 25:75, 50:50 and 75:25, have been tested. A significantly larger number of cuttings were rooted using the 50:50 mixture than with the other combinations.

It has been demonstrated that a double application of rooting hormone, the first being given before insertion of the cuttings, and the second two weeks after the cuttings have set, results in both a greater percentage rooting and a larger number of roots on each cutting. Treating both cut ends of the stem of the cutting with hormone (effectively a double application) gave equally successful results.

The effect of gibberellic acid on cacao

Amounts ranging from 1 to 100 µg. of gibberellic acid were applied to the growing points of 4-week-old seedlings, and to cuttings ten weeks from setting. There was an immediate and considerable increase in the growth rate of the stems of the treated seedlings, but very little effect on the growth of the cuttings. After three weeks all the treated seedlings except those given the lowest concentrations had increased by well over 100 per cent of their pre-treatment length, whereas the control had increased by only 16 per cent. The absence of any effect on the growth of cuttings is being further investigated.

CHEMISTRY DIVISION

SOIL FERTILITY

Effect of major nutrients on cacao

Final yield data for 1957-58 from the Shade and Manurial Trial at W.A.C.R.I. are now available, and are given in Table VI.

TABLE VI

Shade and Manurial Trial - yield data for 1957-58

Treatment	Yield (lb. dry cocoa per acre) 1/4/57 to 31/3/58
Shade without fertilizer	615
Shade with fertilizer*	868
Shade removed only	1080
Shade removed, fertilizer applied*	1576

* Fertilizer applied to date:

Oct.,	1956	Ammonium Phosphate Single Superphosphate	N - 13.4 lb./acre P_2O_5 - 90.7 lb./acre
		Sulphate of Potash	: K_2O - 90.4 lb./acre
		Magnesium Sulphate	: MgO - 45.8 lb./acre
Apr.,	1957	Urea	: N - 50 lb./acre
		Triple Superphosphate	: P_2O_5 - 30 lb./acre
Sept.,	1957	Urea	: N - 50 lb./acre.

An analysis of covariance has been carried out, and it should be noted that the figures given in the Table are actual recorded yields, and not adjusted yields. The results show that:-

(a) the effect of shade removal together with fertilizer mixture application is highly significant (P = .001)

(b) on plots treated with fertilizer the effect of shade removal is highly significant (P = .001)

(c) on plots not treated with fertilizer the effect of shade removal is very significant (P = .01)

(d) on unshaded plots the effect of fertilizer is very significant (P = .01)

(e) on shaded plots the effect of fertilizer is significant (P = .05).

In the fertilizer experiments on mature peasant Amelonado cacao in Ashanti (Quarterly Report No. 45), the first post-treatment harvest has been completed. No significant responses have been observed but at all sites there are encouraging indications that the fertilizer treatments are having beneficial effects.

The final harvest figures for the 2^4 NPKMg factorial experiment at Apedwa and the 2^3 NPK factorial experiment at Bunso, both on Amazon cacao, are not yet available.

The following new experiments are being laid down:

(a) A copper nutritional experiment on yield-recorded mature Amelonado cacao on the Old Station at W.A.C.R.I. This trial is being run in co-operation with the Pathology Division (see p. 5) and includes the following treatments - Control, pods sprayed with carbide-bordeaux, pods sprayed with Perenox, canopy sprayed with copper sulphate, and copper sulphate applied to the soil.

(b) A field trace element experiment on yield-recorded 13-year-old Amelonado cacao at Adonkwanta. The minor elements being investigated are iron, manganese, zinc, copper, boron and molybdenum.

(c) On Amelonado cacao at W.A.C.R.I., an experiment with the major nutrients nitrogen, phosphorus, potassium and magnesium in which each element is applied at three levels in combination with a basal dressing of the other three nutrients.

(d) On Amazon cacao at W.A.C.R.I., a 2^4 NPKMg factorial experiment with four replications and the third order interaction confounded.

COCOA PREPARATION AND QUALITY

Pregermination

Pregermination of cocoa beans is often associated with damage to the pod wall, and it has been suggested that an increased

rate of diffusion of oxygen through the damaged wall may be a contributing factor. Experiments have accordingly been carried out to estimate gaseous oxygen concentration in ripe pods. Various techniques for sampling the gas in the cavity of a pod have been tested, and the most satisfactory method used has been to withdraw the gas with a hypodermic syringe, carrying out the whole operation under water. The samples of gas were then analysed for carbon dioxide and oxygen in the conventional way by measuring the reduction in volume which followed the addition, firstly of potassium hydroxide solution and secondly of alkaline pyrogallol. With ripe undamaged West African Amelonado pods the oxygen content of the cavity gas was 15.5 to 16.0 per cent by volume and the carbon dioxide content 5.0 to 6.5 per cent by volume.

Since the oxygen content of the cavity gas of sound pods is only a little less than that of air it seems unlikely that any increase in the oxygen content which might be brought about by damage to the pod wall would increase the likelihood of germination.

I B A D A N S U B - S T A T I O N

PATHOLOGY SECTION

VIRUS RESEARCH

Strains of Nigerian cacao viruses

In recent years attempts have been made to obtain mild strains of some of the cacao viruses present in Nigeria. In the course of this work several isolates have been obtained which have little effect on the growth of cacao and which produce only transient or inconspicuous symptoms and no swellings on the aerial parts. Some of these viruses are now being studied in detail and experiments are in progress to determine their ability to protect plants from the effect of subsequent inoculation with a range of virulent viruses from a number of different localities. In this way it may be possible to demonstrate relationships between some of the viruses from Nigeria. Furthermore it may be possible to use some of the mild viruses in the areas of mass infection to protect new plantings from the effects of virulent virus.

Nine isolates of mild virus have been obtained from trees in the Koroboto Observation plot in the Ibadan area of mass infection. These trees had been selected as showing inconspicuous symptoms and these only at infrequent intervals. Plants infected

in transmission tests from them caused mild symptoms on seedlings infected by grafts or by insects and further transmissions are being carried out from the most vigorous of these plants in an attempt to obtain particularly mild forms of virus.

The situation in the Koroboto plot is similar to that described by Posnette and Todd (Ann. appl. Biol. 43, 433, 1955) from their observations on farms in the New Juaben areas of the Eastern Province of Ghana. In both countries different trees in a restricted area may contain viruses which differ considerably in virulence and in the symptoms they cause. Thus some isolates cause swellings as the only consistent and permanent symptoms, others cause only a reticulate mosaic, whereas most produce leaf symptoms and swellings and a few are virtually latent. This complex state of affairs in what appear to be single outbreaks is not atypical and similar results have been obtained in less detailed experiments elsewhere in Ghana and in Nigeria. It is possible that cacao viruses are particularly unstable and continually giving rise to new forms which become segregated during the normal course of spread. Alternatively the mealybugs may carry more than one form of virus when they start new outbreaks by reaching healthy cacao from outside sources of infection. Further work is planned to elucidate this point and one approach is to investigate the range of viruses present in very small outbreaks or in single isolated trees which have been naturally infected in areas of otherwise healthy cacao.

The mild forms of the virus present at Koroboto are not unique and similar ones have been obtained from all the outbreaks which have been investigated in detail including some at Aladie in Ilaro Province and others at Balogun and Ikire in Ibadan Province. A particularly mild form was obtained in a series of experiments primarily designed to investigate the effect of infestation rate on the type and appearance of the symptoms caused by an isolate from Ikire. One plant was infected by two mealybug nymphs and showed very mild symptoms, while it was conspicuously more vigorous than the other infected plants. Plants infected in subsequent transfers had average leaf area of 876.1 sq. cm. after sixteen weeks compared with comparable healthy controls with an area of 915.9 sq. cm. and plants infected with the usual virus from Ikire which had an average leaf area of 435.6 sq. cm.

STUDIES ON "DIE-BACK" OF CACAO

Existing areas

The results of three monthly observations on three hundred trees at Araromi (see Quarterly Report No. 47) have recently been analysed. Of the 1346 areas of "die-back" marked at the beginning of the experiment 10 per cent have increased in size. In some cases increases were observed over one month only, in others over each of two successive months and some areas increased between each observation. "Die-back" advanced an average of six to ten inches each month but there were great variations and some areas advanced as much as eighty inches. The increase in extent of the "die-back" areas was apparently independent of the initial size of the dead area, and also independent of the general condition of the tree and of the position of the marked areas on the tree.

Isolation of fungi from dead cacao tissues

Numerous isolations have been made of the fungi occurring in dead cacao tissues. The material examined comprised one hundred wounds caused by mechanical damage, one hundred areas of "die-back" selected at random and one hundred areas of "die-back" that occurred in the absence of capsid damage. The results are set out in Table VII.

TABLE VII

Percentage distribution* of fungi in dead cacao tissues

	Mechanical wounds	"Dieback"	"Dieback" in the absence of capsid damage
Fusarium decemcellulare	36	24	36
Botryodiplodia theobromae	25	40	25
Fusarium/Botryodiplodia	6	26	6
Other fungi	23	13	23
Sterile	16	23	16

* One hundred isolates made of each type of tissue.

F. decemcellulare and B. theobromae were consistently isolated from dead cacao tissue, either singly or together. However, a high proportion of the areas examined yielded isolates of other fungi than F. decemcellulare and B. theobromae or remained sterile.

From numerous examinations of areas of "die-back" it has been observed that in longitudinal section an outer greyish-coloured zone of dead wood adjoins a narrow claret-coloured zone that quickly blackens on exposure. The claret-coloured zone is usually separated from healthy tissues by a water-soaked area, which is apparently sterile. By contrast F. decemcellulare was usually isolated from the intermediate zones, although B. theobromae was occasionally present. B. theobromae was always isolated in areas where the water-soaked zone was absent.

An experiment designed to show the importance of capsid lesions in initiating "die-back" has been started. On two mature cacao trees that have been severely damaged by capsids, the capsid lesions have been counted on one hundred different twigs and a general description of the twig has been made. The two trees have subsequently been sprayed against capsids.

The effect of the presence of Calonectria rigidiuscula (Berk & Br.) Sacc. in coppiced stumps, on the regeneration of cacao

An analysis of the results obtained from cacao trees coppiced in June last year, showed that the C. rigidiuscula inoculated into the coppiced stumps had no apparent effect on regeneration and C. rigidiuscula was re-isolated from only three of the stumps.

A further ninety trees have been coppiced and inoculated with pure cultures of C. rigidiuscula. Chupons are rapidly developing from cushions on most of the stumps.

The effect on "die-back" of fungicidal sprays and pruning

In a plot of over two hundred cacao trees the following treatments are being compared, with untreated plots as control:

1) Pruning away all existing areas of "die-back"
2) Pruning, combined with a general high-volume spraying with a 3% solution of a mercury-synergised copper fungicide
3) Pruning, combined with a general high-volume spraying with a 6% solution of a copper fungicide.

On the control plots the increase in size of the existing areas of "die-back" is being measured and in all the plots the incidence of new areas of "die-back" is being recorded.

The effect on "die-back" of irrigation during the dry season

During the past four months 37 trees have been irrigated in a plot of 74 cacao trees, all of which were sprayed against capsids. Irrigation had no effect on the increase in size of

existing dead areas and only slightly reduced the incidence of new areas of "die-back".

Inoculation experiments

Spores of F. decemcellulare were inoculated into wounds made up with a 3 mm. needle in the stem tissue of 15-month-old Amelonado seedlings. After five months none of the seedlings showed any signs of dying back, but on the stem surface the wounds have increased in size.

The effects of varying the water supply, shade conditions and degree of defoliation are being studied in relation to the spread of lesions made by a sterile needle, and also by a needle contaminated with spores of F. decemcellulare, in the stems of 12 to 16-months-old Amelonado seedlings.

ENTOMOLOGY SECTION

MEALYBUG STUDIES

The examination of the mealybug population on two plots of cacao on Moor Plantation, which was begun at the end of November, 1957, has been continued. The most striking changes noted during the quarter have been the virtual disappearance of Pseudococcus njalensis Laing from trees on the "bush plots", and the increase in the number of Ferrisiana virgata (Ckll.) during the latter half of the quarter. The former may be due to a seasonal fluctuation, or it may be because the earlier records came from one end of the plot and the later ones mainly from a group of trees in the middle of the plot, separated from the earlier trees by a patch of bush regrowth in which all the cacao had died. The increase in the numbers of F. virgata followed a heavy flush of new growth after the storms of mid-February, providing abundant suitable feeding sites for this species which appears to prefer very young tissues. Thirty-three per cent of all colonies examined in March contained F. virgata whereas in November and December the comparable figures were both less than 6 per cent.

Five adults of a species new to the W.A.C.R.I. collection have been found. These will be sent to the Commonwealth Institute of Entomology for identification.

CACAO STEM BORERS

Reports of "shot-hole borer" damage were received from a number of areas during the quarter and visits were paid to some

of these localities. At Akure Farm large numbers of young seedlings have died and even branches of well-grown three-year-old trees have been affected. Examination of these plants showed that the majority of the beetles were of the genus Stephanoderes which were entering the stems only after severe wilting had occurred. A few specimens of Xyleborus morstatti Hag. and Poecilips confusus Egg. were also found. X. morstatti is the only species which is known to attack apparently healthy seedlings, and it was not sufficiently common to have caused more than a very small proportion of the deaths observed. In batches of seedlings of which some of the leaves still showed signs of greeness 60 per cent had no beetle attack whereas only 30 per cent of those with all leaves dead were free from beetle borings. The majority of the beetles had entered the stems through old dried leaf scars, or through the bases of dead leaf petioles which had failed to abscise. The prime cause of death of the majority of seedlings is considered to have been drought and most of the beetle attack appears to be of a secondary nature and to have occurred only after the plants had either died or wilted severely.

A few seedlings at Akure and others at Apoje had been attacked by a species of weevil (Curculionidae) the larvae of which bore into the stems at ground level. An anthribid was also reared from a larva doing similar damage at Apoje. This has previously been recorded from seedlings at Aponmu near Akure. A further species of weevil is represented by a single adult reared from a pupa in a boring about two feet from the ground.

Adults of Apate monacha Fab. (Bostrychidae) were found boring into well-grown cacao plants, three to four years of age, over an area of about quarter of an acre at Apoje. About 70 per cent of the best seedlings were affected, most of them with several entry holes leading into very extensive galleries. Smaller seedlings which had been used to fill "vacancies" were not damaged. It was later reported that two other small areas of cacao on the plantation were similarly attacked. Shade had been severely thinned in the first area towards the end of the previous dry season and this probably encouraged attack by these pests, which have been recorded from a number of tree crops, particularly when growing in exposed situations.

Specimens of all the above beetles will be sent to the Commonwealth Institute of Entomology for identification.

Larvae of the moth borer Eulophonotus myrmeleon Feld. (Lep: Megalopygidae) were frequently found attacking fan branches

of large seedlings and mature trees.

INSECT TRANSMISSION OF CACAO VIRUSES

The virus isolate from Asalu/Nigeria for which the name "cacao necrosis virus" has been proposed (see Quarterly Report No. 45) does not so far appear to be transmitted by mealybugs. More detailed experiments are in progress and other insects occurring on cacao and cola are being tested for their ability to transmit cacao necrosis virus. Tests have included the aphids Toxoptera citricidus Kirkaldy, Toxoptera aurantii B.d.F., the cacao psyllid Tyora tessmanni Aulm. and the mealybug Ferrisiana virgata (Ckll.), but no transmissions have been recorded as yet. Cacao necrosis virus occurs in the main cola growing areas and the susceptibility of Cola spp. to this virus is being investigated.

Transmission tests with single insects have been started using test-plants infected simultaneously with the isolates from Elepo and Alaparun. These tests should provide more data on the availability of virus in plants and possible selective transmission by the species used. Experiments have been started to investigate the problem of virus complexes occurring in cacao trees using single insect transfers and it is hoped that this will be of use in the work on strain relationships.

SOA.